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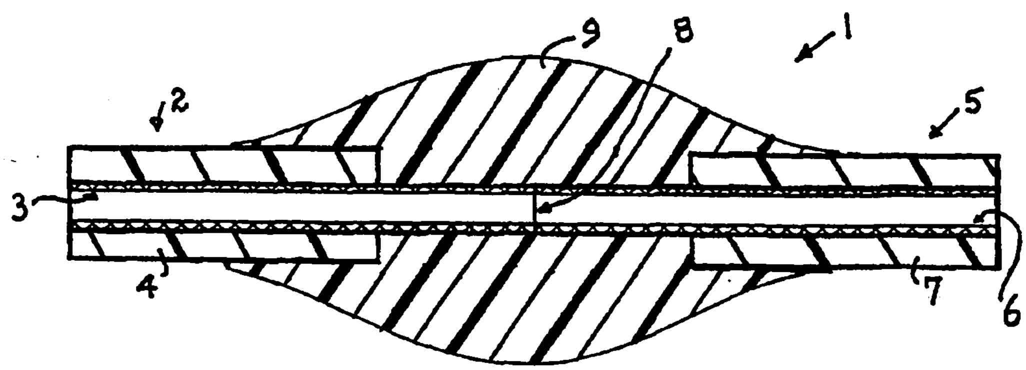

(57) Abstract

A power induction device including at least one cable joint assembly (1) having: a first cable (2) with inner first conducting means (3), comprising first conductor means (21) cooled by first cooling means (22) and surrounding outer first electrical insulation (4); a second cable (5) having inner second conducting means (6) and surrounding outer second electrical insulation (7); one end of the first conducting means (3) being joined at a joint (8) to one end of the second conducting means (6), the outer electrical insulation (4, 7) of each cable not surrounding an end portion of its associated inner conducting means adjacent the one end of the latter; and polymeric electrically insulating means (9) surrounding the joint (8) and the end portions of the first and second conducting means (3, 6). The first electrical insulation comprises inner and outer layers of semiconducting material and an intermediate layer of insulating material. The invention also relates to a method of joining together two power cables in a power induction device.

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A POWER INDUCTION DEVICE

Technical Field

This invention relates to a power induction device including at least one cable joint assembly for connecting together two high voltage cables, e.g. operating at up to 800 kV or higher, at least one of which cables is cooled in use to a low temperature to improve its electrical conductivity. In particular, but not exclusively, the invention relates to a power induction device in which the at least one cable joint assembly connects together a superconducting power cable, preferably a so-called high-temperature (high-T_c) superconducting (HTS) power cable, to another HTS cable or any other type of high voltage cable. The power induction device may comprise, for example, a fault current limiter, a transformer, motor, generator or magnetic energy storage device, such as a SMES device. The invention also relates to a method of joining together two high voltage or power cables in a power induction device, at least one of which cables is cooled in use to a lower temperature to improve its electrical conductivity.

State of the Art

In a power induction device, the joining together of high voltage power cables having electrical conductors which operate at normal room or ambient temperatures is well known. In such a known cable joint, it is conventional for the electrical insulation to be stripped from end regions of the cables to be joined to reveal the underlying electrical conductors. These electrical conductors are then joined, e.g. soldered, welded or mechanically joined, together and the joined together conductors are surrounded at the joint by polymeric material. An example of such a joint in which the polymeric material comprises a cross-linked polymer tape is discl sed in US-A-4,084,307. However in other known joints the polymeric material may be in the form of a

prefabricated joint, an elastomer taped joint which is self-amalgamating or an extruded or taped layer of the polymeric material which is cross-linked _in situ_.

The joining together in a power induction device of two cooled, e.g. superconducting, cables is more complex than the joining together of conventional, non-cooled cables since it requires the joining together of conduits for cryogenic cooling fluids, the joining together of conducting means, e.g. superconducting tapes or threads, and the provision of electrical insulation around the joint. Conventionally it has been necessary to ensure that the electrical insulation surrounding the joint is not subjected to a large thermal gradient which may result in mechanical stress and degradation of the insulation. In practice conventional electrical insulation is thermally insulated externally so that it is close to the temperature of the inner cooled conductors and/or is thermally insulated inwardly between itself and the inner conductors so that it is not cooled close to cryogenic temperatures.

Summary of the Invention

An aim of the present invention is to provide in a power induction device an improved cable joint assembly for joining together two high voltage cables, at least one of which is cooled in use to a low temperature to improve its electrical conductivity, and an improved method of joining together two such cables in a power induction device.

According to one aspect of the present invention there is provided a power induction device including at least one cable joint assembly comprising:

a first cable having inner first conducting means and surrounding outer first electrical insulation, the first conducting means comprising first conductor means and first cooling means for cooling the first conductor means to improve the electrical

conductivity of the first conductor means and the first electrical insulation (4) comprising a first inner layer of semiconducting material electrically connected to the first conductor means, a first outer layer of semiconducting material connected to a controlled electric potential, e.g. earth potential, along its length, and a first intermediate layer of solid electrically insulating material between said semiconducting first inner and outer layers;

a second cable having inner second conducting means and surrounding outer second electrical insulation;

one end of the first conducting means being joined at a joint to one end of the second conducting means, the said outer electrical insulation of each cable not surrounding an end portion of its associated inner conducting means adjacent the said one end of the latter; and

polymeric electrically insulating means surrounding the said joint and the said end portions of the first and second conducting means.

In this specification the term "semiconducting material" means a substance which has a considerably lower conductivity than an electric conductor but which does not have such a low conductivity that it is an electric insulator. Suitably, but not exclusively, the semiconducting material will have a resistivity of from 1 to 10^5 ohm·cm, preferably from 10 to 500 ohm·cm and most preferably from 10 to 100 ohm·cm, typically about 20 ohm·cm.

Conveniently the polymeric electrically insulating means is arranged to surround the or each joint assembly in the power induction device and the said end portions of the first and second conducting means without any intervening thermal insulation. Thus in such a design the polymeric

electrically insulating means will operate in use at or close to cryogenic temperatures.

A layer of semiconducting material may be provided on the inside and/or outside of the polymeric electrically insulating means.

The polymeric electrically insulating means may comprise a prefabricated polymeric sleeve, a polymeric extrusion extruded around the joint or a polymeric tape wrapped around the joint. In the case of polymeric tape or extruded layer, the material may be cross-linked or may contain a cross-linking agent which is cross-linked by heat and pressure after its application around the joint.

Examples of polymeric materials for the polymeric electrically insulating means comprise low or high density polyethylene (LDPE or HDPE), polypropylene (PP), polybutylene (PB), polymethylpentene (PMP), ethylene (ethyl) acrylate polymer, cross-linked (or cross-linkable) materials, such as cross-linked polyethylene (XLPE), or rubber insulation, such as ethylene propylene rubber (EPR) or silicone rubber.

Preferably the first conductor means comprises first superconducting means and the first cooling means, in use, cools the first superconducting means to superconducting temperatures.

Preferably the second conducting means comprises second conductor means and second cooling means for cooling the second conductor means to improve the electrical conductivity of the second conductor means. Conveniently, the second conductor means comprises second superconducting means and the second cooling means, in use, cool the second superconducting means to superconducting temperatures.

Conveniently the or each of said cooling means comprises an inner tube of metal or metal alloy, preferably of high electrical resistivity, through which cryogenic

cooling fluid, e.g. liquid nitrogen, is passed. In the case where the or each conductor means comprises superconducting means, the superconducting means comprises elongate superconducting material, preferably HTS material, e.g. in tape or thread form, helically wound around its associated inner tube. If both the first and second conductor means comprise superconducting means, the inner tubes are suitably mechanically joined, e.g. welded, together at the joint and electrical connection is made between end regions of the elongate superconducting materials of the first and second superconducting means. The helically wound HTS material is cooled to below the critical temperature T_c of the HTS by the cooling fluid passing through the inner tubes.

There are many different types of HTS material which are normally ceramic materials. A typical example of elongate HTS material in thread or tape form comprises silver-sheathed BSCCO-2212 or BSCCO-2223 (where the numerals indicate the number of atoms of each element in the $[Bi, Pb]_2 Sr_2 Ca_2 Cu_3 Ox$ molecule). BSCCO threads or tapes are made by encasing fine filaments of the oxide superconductor in a silver or silver oxide matrix by a powder-in-tube (PIT) draw, roll, sinter and roll process. Alternatively the threads or tapes may be formed by a surface coating process. In either case the oxide is melted and resolidified as a final process step. Other HTS threads or tapes, such as TiBaCaCuO (TBCCO-1223) and YBaCuO (YBCO-123) have been made by various surface coating or surface deposition techniques. Two HTS threads, each having an outer electrically conductive, e.g. metallic (silver), layer, can be joined together by joining the conductive layers of the two threads. For example end portions of two such HTS threads can be overlapped and the silver outer layers can be soldered together. In this case, the silver layers act as "bridges" connecting the HTS material together.

Preferably the second electrical insulation has second inner, outer and intermediate layers similar to the

first inner layer, first outer layer and first intermediate layer of the first electrical insulation.

The or each of the intermediate layers preferably comprises polymeric material such as, for example, low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), cross-linked materials such as cross-linked polyethylene (XLPE) or rubber insulation such as ethylene propylene rubber (EPR) or silicone rubber. The semiconducting layers of the first electrical insulation or on the inner and/or outer layers of the polymeric electrically insulating means are formed of similar polymeric materials but with highly electrically conductive particles, e.g. of carbon black or metal, embedded therein. Typical examples of materials for the insulating and semiconducting layers are disclosed in US-A-4,785,138.

According to another aspect of the present invention there is provided a method of joining together in a power induction device a first cable having inner first conducting means and surrounding outer first electrical insulation, the first conducting means comprising first conductor means and first cooling means for cooling the first conductor means to improve the electrical conductivity of the first conductor means, and the first electrical insulation comprising a first inner layer of semiconducting material electrically connected to the first conductor means, a first outer layer of semiconducting material connected to a controlled electric potential, e.g. earth potential, along its length, and a first intermediate layer of solid electrically insulating material between said semiconducting first inner and outer layers, and a second cable having inner second conducting means and surrounding outer second electrical insulation, the method comprising removing the electrical insulation from an end portion of each cable to reveal the underlying conducting means, joining together the said end portions of the first and second conducting means so that the conducting means are joined together end to end at a joint, and surrounding the joint and said end portions of

the inner first and second conducting means with electrically insulating means.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only, with particular reference to the accompanying drawing, in which:

Figure 1 is a schematic sectional view of a cable joint assembly of a power induction device according to the present invention;

Figure 2 is a schematic partial sectional view, on an enlarged scale, of a high voltage power cable of the cable joint assembly;

Figure 3 is a schematic sectional view illustrating the joining together of two overlapping super-conducting threads of a joint assembly of a power induction device;

Figure 4 is a schematic view of a joint assembly for connecting together two power cables of a power induction device; and

Figure 5 is a detail, on an enlarged scale of part of a joint of the joint assembly of Figure 4.

Figure 1 shows a joint assembly, generally designated by the reference numeral 1, of a power induction device. The joint assembly comprises a first superconducting cable 2 having elongate inner superconducting means 3 and outer electrical insulation 4, a second superconducting cable 5 having elongate inner superconducting means 6 and outer electrical insulation 7, the superconducting means 3 and 6 being joined end to end at joint 8, and polymeric electrical insulation 9 surrounding the joint 8. End portions of the electrical insulation 4 and 7 have been removed to reveal end portions of the superconducting means 3, 6 on either

sid of the joint 8. The first superconducting cable 2 may, for example, form an inductive winding f the induction device and the second superconducting cable 5 may comprise an input or output connection to the induction device. Alternatively, for example, the joined cables may comprise parts of the same winding of the power induction device.

Figure 2 shows one of the superconducting cables 2 (the other cable 5 being of substantially similar design) of the joint assembly 1 shown in Figure 1. The elongate inner superconducting means 3 comprises an inner metal, e.g. copper or highly resistive metal or alloy, support tube 21 and an HTS wire 22 wound helically around the tube 21 and embedded in a layer 23 of semiconducting, e.g. plastics, material. The electrical insulation 4 is arranged outwardly of, at a small radial spacing 24 from, the layer 23. This electrical insulation 4 is substantially void-free and comprises an inner semiconducting layer 25, an outer semiconducting layer 26 and, sandwiched between these semiconducting layers, an insulating layer 27. The layers 25-27 are formed of solid material and preferably comprise thermoplastics materials connected to each other at their interfaces. Conveniently these thermoplastics materials have similar coefficients of thermal expansion (α) and are preferably extruded together around the inner superconducting means 3. Preferably the layers 25-27 are extruded together to provide a monolithic structure so as to minimise the risk of cavities and pores at the interfaces of the electrical insulation. The presence of such pores and cavities in the insulation and at its interfaces is undesirable since it gives rise to corona discharge in the electrical insulation at high electric field strengths.

The outer semiconducting layer 26 is connected along its length, e.g. at spaced apart regions along its length, to a controlled potential. In most practical applications this controlled potential will be earth or ground potential. The specific spacing apart of spaced apart adjacent earthing points is dependent on the resistivity of the layer 26.

The semiconducting layer 26 acts as a static shield and as an earthed outer layer which ensures that the electric field of the superconducting cable is retained within the solid insulation between the semiconducting layers 25 and 26. Losses caused by induced voltages in the layer 26 are reduced by increasing the resistance of the layer 26. However, since the layer 26 must be at least of a certain minimum thickness, e.g. no less than 0.8 mm, the resistance can only be increased by selecting the material of the layer to have a relatively high volume resistivity. The resistivity cannot be increased too much, however, else the voltage of the layer 26 mid-way between two adjacent earthing points will be too high with the associated risk of corona discharges occurring.

The radial spacing 24 provides an expansion/contraction gap to compensate for the differences in the thermal coefficients of expansion (α) between the electrical insulation 4 and the inner superconducting means 3 (including the metal tube 21). The spacing 24 may be a void space or may incorporate a foamed, highly compressible material to absorb any relative movement between the superconductor and insulation system. The foamed material, if provided, may be semiconductive to ensure electrical contact between the layers 23 and 25. Additionally or alternatively, metal wires may be provided for ensuring the necessary electrical contact between the layers 23 and 25.

The HTS wire 22 is cooled to cryogenic temperatures by the passage of a cooling fluid, e.g. liquid nitrogen, through the tube 21.

By way of example only the semiconducting material of each of the layers 23, 25 and 26 may comprise, for example, a base polymer, such as ethylene-propylene copolymer rubber (EPRM) or ethylene-propylene-diene monomer rubber (EPDM), and highly electrically conductive particles, e.g. particles of carbon black embedded in the base polymer. The volume resistivity of these semiconducting layers may be adjusted

as required by varying the type and proportion of carbon black added to the base polymer. The following gives an example of the way in which volume resistivity can be varied using different types and quantities of carbon black.

Base Polymer	Carbon Black Type	Carbon Black Quantity (%)	Volume Resistivity Ω·cm
Ethylene vinyl acetate copolymer/ nitrite rubber	EC carbon black	~15	350-400
-"-	P-carbon black	~37	70-10
-"-	Extra conducting carbon black, type I	~35	40-50
-"-	Extra conducting black, type II	~33	30-60
Butyl grafted polyethylene	-"-	~25	7-10
Ethylene butyl acrylate copolymer	Acetylene carbon black	~35	40-50
-"-	P carbon black	~38	5-10
Ethylene propene rubber	Extra conducting carbon black	~35	200-400

The HTS wire 22 may suitably comprise a core 20 of an alloy of superconducting material (see Figure 3) sheathed in an electrically conductive outer layer 21, e.g. of silver or silver alloy. Typical of such an HTS wire are silver-sheathed BSCCO-2212 or BSCCO-2223. In order to join together two such HTS wires, the ends of the wires may be overlapped as shown in Figure 3 and the conductive outer layers 21 soldered or otherwise joined together. The length of the overlap should be sufficient to provide a good electrical contact of the outer layers. Since the inner cores 20 are in electrical contact with their conductive outer layers 21, the latter act as "bridges" for electrically connecting the inner cores together.

The polymeric electrical insulation 9 is shown schematically in Figure 1. The polymeric insulation may be in the form of a prefabricated joint or sleeve, an elastomer taped joint which is self-amalgamating or an extruded or

taped layer of the polymeric material which is cr ss-linked in situ. Examples of polymeric materials for the polymeric electrically insulating means comprise low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), cross-linked (or cross-linkable) materials, such as cross-linked polyethylene (XLPE), or rubber insulation, such as ethylene propylene rubber (EPR) or silicone rubber. In the embodiment described, no thermal insulation and no cryostat is positioned between the insulation 9 and the inner superconducting means. A layer (not shown) of semiconducting material may be provided inwardly and/or outwardly of the insulation 9, although it may not be necessary for the layer(s) to extend over the entire axial extent of the inner/outer surface(s) of the insulation 9. If a semiconducting inner layer is provided it will make electrical contact with the superconducting means 6. If a semiconducting outer layer is provided, it will be at a controlled, e.g. earth, potential along its length. The semiconducting material may be the same as that used for the layers 23, 25 and 26.

Although the cables 2 and 5 are shown as being of generally similar design, the thickness of the outer electrical insulation 4 may be different to the thickness of the outer electrical insulation 7. Thus, for example, if the joined together cables 2 and 5 form at least part of a transformer winding, with the cable 2 being at a higher operating voltage, in use, than the cable 5, then the insulation 4 may be thicker than the insulation 7. By providing each winding with joined together power cables of different diameters, and by intermixing different windings, it is possible to optimise the space occupied by the windings.

In joining together two cables 2 and 5, the end portions of the cables to be joined are stripped of the electrical insulation 4 and 7, respectively. Then the inner metal support tubes are welded together and the HTS wires are joined together. Finally the polymeric electrical

insulation 9 is applied around the joint 8 and the uncovered end portions of the support tubes.

Figures 4 and 5 show in a power induction device an alternative joint assembly for connecting together a superconducting cable 31 and an earthed non-superconducting cable 38 electrically insulated by solid electrically insulating material 40. The superconducting cable 31 has a central tube 32 having a return bend at one end 33 of the cable to form a generally U-shaped tube having coolant supply and return ducts 34 and 35 in communication with each other. Superconducting means, in the form of elongate superconducting wire or tape having conductive strands 42, is wound around the central tube 32 with the conductive strands 42 being joined, e.g. soldered, at joint 36 to the current conductor(s) 37 of the cable 38.

The superconducting wire or tape wound around the central tube 32 is electrically insulated by typically void-free, solid insulating material 39 comprising an inner layer of semiconducting material electrically connected to the superconducting means, an outer layer of semiconducting material connected to a controlled electric potential, preferably earth potential, along its length and an intermediate layer of electrically insulating material. Conveniently these layers of the electrical insulation are of similar material, e.g. polymeric material, and are formed in a similar manner to the layers of the electric insulation 7 described with reference to the Figure 2. The electrical insulation 40 may be similar to the insulation 39, having inner and outer layers of semiconducting material and an intermediate layer of insulating material. Conductors of the cable 38 are connected to the inner semiconducting layer and the outer semiconducting layer is at a controlled, e.g. earth, potential along its length.

The joint 36 is surrounded by polymeric electrical insulation 41. The insulation 41 surrounds the soldered together superconducting strands 42 and current conductor(s)

37 and overlaps both the insulating material 39 and the insulating material 40.

The central tube may comprise a single tube (not shown) divided by an internal partition to provide supply and return ducts for the cryogenic fluid which are in communication with each other at the end 33. The cooling efficiency can be slightly improved by constructing the support tube and/or its inner partition as a helix so that the surrounding superconducting wire or tape is cooled along a helical path. Alternatively the support tube could be designed as a pair of concentric tubes, the inner tube serving as a return duct for the cryogenic fluid, the superconducting wire or tape being wound on the outside of the outer tube and the annular gap between the inner and outer tubes providing a supply duct for the cryogenic fluid.

The invention is not limited to a power induction device having at least one joined superconducting cable or cables of the type disclosed in Figure 2. Indeed the or each joint assembly of a power induction device according to the invention is intended to cover the use of polymeric electrical insulation which is able to operate at or close to cryogenic temperatures.

Although the present invention is primarily directed to power induction devices having joints for high voltage power cables at least one of which has conducting means with superconducting properties which are cooled to superconducting temperatures in use, the invention is also intended to embrace power induction devices having power cable joints in which at least one of the high voltage power cables has conducting means having improved electrical conductivity at a low operating temperature, up to, but preferably no more than, 200 K, but which may not possess superconducting properties at least at the intended low operating temperatur . At these higher cryogenic temperatures, liquid carbon dioxide can be used for cooling the conducting means.

The electrical insulation used in a joint of a power induction device according to th invention is intended to be able to handle very high voltages and the consequent electric and thermal loads which may arise at these voltages. By way of example, a power induction device according to the invention may comprise a power transformer having a rated power of from a few hundred kVA up to more than 1000 MVA and with a rated voltage ranging from 3-4 kV up to very high transmission voltages of 400-800 kV. At high operating voltages, partial discharges, or PD, constitute a serious problem for known insulation systems of power induction devices. If cavities or pores are present in the insulation, internal corona discharge may arise whereby the insulating material is gradually degraded eventually leading to breakdown of the insulation. The electric load on the electrical insulation of a cable of a power induction device according to the present invention is reduced by ensuring that the inner layer of the insulation is at substantially the same electric potential as the inner conducting means and the outer layer of the insulation is at a controlled, e.g. earth, potential. Thus the electric field in the intermediate layer of insulating material between the inner and outer layers is distributed substantially uniformly over the thickness of the intermediate layer. Furthermore, by having materials with similar thermal properties and with few defects in the layers of the insulating material, the possibility of PD is reduced at a given operating voltages. A joint of a power induction device can thus be designed to withstand very high operating voltages, typically up to 800 kV or higher.

Power induction devices according to the invention may comprise, for example, motors, generator, transformers, energy storage devices, such as SMES devices, or fault current limiters.

Although it is preferred that the electrical insulation should be extruded in position, it is possible to build up an electrical insulation system from tightly wound,

overlapping layers of film r sheet-like mat rial. Both the semiconducting layers and the electrically insulating layer can be formed in this manner. An insulation system can be made of an all-synthetic film with inner and outer semiconducting layers or portions made of polymeric thin film of, for example, PP, PET, LDPE or HDPE with embedded conducting particles, such as carbon black or metallic particles and with an insulating layer or portion between the semiconducting layers or portions.

For the lapped concept a sufficiently thin film will have butt gaps smaller than the so-called Paschen minima, thus rendering liquid impregnation unnecessary. A dry, wound multilayer thin film insulation has also good thermal properties and can be combined with a superconducting pipe as an electric conductor and have coolant, such as liquid nitrogen, pumped through the pipe.

Another example of an electrical insulation system is similar to a conventional cellulose based cable, where a thin cellulose based or synthetic paper or non-woven material is lap wound around a conductor. In this case the semiconducting layers, on either side of an insulating layer, can be made of cellulose paper or non-woven material made from fibres of insulating material and with conducting particles embedded. The insulating layer can be made from the same base material or another material can be used.

Another example of an insulation system is obtained by combining film and fibrous insulating material, either as a laminate or as co-lapped. An example of this insulation system is the commercially available so-called paper polypropylene laminate, PPLP, but several other combinations of film and fibrous parts are possible. In these systems various impregnations such as mineral oil or liquid nitrogen can be used.

CLAIMS

1. A power induction device including at least one cable joint assembly (1) comprising:

- a first cable (2) having inner first conducting means (3) and surrounding outer first electrical insulation (4), the first conducting means (3) comprising first conductor means (21) and first cooling means (22) for cooling the first conductor means to improve the electrical conductivity of the first conductor means (22) and the first electrical insulation (4) comprising a first inner layer of semiconducting material electrically connected to the first conductor means, a first outer layer of semiconducting material connected to a controlled electric potential, e.g. earth potential, along its length, and a first intermediate layer of solid electrically insulating material between said semiconducting first inner and outer layers;

- a second cable (5) having inner second conducting means (6) and surrounding outer second electrical insulation (7);

- one end of the first conducting means (3) being joined at a joint (8) to one end of the second conducting means (6), the said outer electrical insulation (4, 7) of each cable not surrounding an end portion of its associated inner conducting means adjacent the said one end of the latter; and

- polymeric electrically insulating means (9) surrounding the said joint (8) and the said end portions of the first and second conducting means (3, 6).

2. A power induction device according to claim 1, characterised in that said polymeric electrically insulating means (9) surrounds the said joint (8) and the said end portions of the first and second conducting means (3, 6) without any intervening thermal insulation.

3. A power induction d vice according to claim 1 or 2, characterised in that said polymeric electrically insulating means (9) comprises a prefabricated polymeric sleeve.

4. A power induction device according to claim 1 or 2, characterised in that said polymeric electrically insulating means (9) comprises a polymeric extrusion extruded around the joint (8).

5. A power induction device according to claim 1 or 2, characterised in that said polymeric electrically insulating means (9) comprises a polymeric tape wrapped around the joint.

6. A power induction device according to claim 5, characterised in that said polymeric tape is cross-linked.

7. A power induction device according to any one of the preceding claims, characterised in that inwardly of said polymeric insulating means (9) there is a layer of semiconducting material.

8. A power induction device according to any one of the preceding claims, characterised in that outwardly of said polymeric insulating means (9) there is a layer of semiconducting material.

9. A power induction device according to any one of the preceding claims, characterised in that said polymeric electrically insulating means comprises low or high density polyethylene (LDPE or HDPE), polybutylene (PB), polymethylpentene (PMP), ethylene (ethyl) acrylate polymer, cross-linked materials or rubber insulation.

10. A power induction device according to claim 9, characterised in that said cross-linked materials comprise cross-linked polyethylene (XLPE).

11. A power induction device according to claim 9, characterised in that said rubber insulation comprises ethylene propylene rubber (EPR) or silicone rubber.

12. A power induction device according to any one of the preceding claims, characterised in that the first conductor means comprises first superconducting means and the first cooling means, in use, cools the first superconducting means to superconducting temperatures.

13. A power induction device according to any one of the preceding claims, characterised in that the second conducting means comprises second conductor means and second cooling means for cooling the second conductor means to improve the electrical conductivity of the second conductor means.

14. A power induction device according to claim 13, characterised in that the second conductor means comprises second superconducting means and the second cooling means, in use, cools the second superconducting means to superconducting temperatures.

15. A power induction device according to any one of the preceding claims, characterised in that the or each of said cooling means comprises an inner tube through which cryogenic cooling fluid, e.g. liquid nitrogen, is passed.

16. A power induction device according to claim 15 when dependent on claim 12 or 14, characterised in that the or each of said superconducting means comprises elongate superconducting material helically wound around its associated inner tube.

17. A power induction device according to claim 16 when dependent on claim 14, characterised in that the two inner tubes are mechanically joined, e.g. welded, together at the joint.

18. A power induction device according to any one of th preceding claims, characterised in that the second electrical insulation (7) comprises a second inner layer of semiconducting material electrically connected to the second conducting means, a second outer layer of semiconducting material connected to a controlled electric potential, e.g. earth potential, along its length, and a second intermediate layer of solid electrically insulating material between said semiconducting second inner and outer layers.

19. A power induction device according to any one of the preceding claims, characterised in that the said semiconducting material has a resistivity of from 1 to 10^5 ohm-cm, preferably from 10 to 500 ohm-cm and most preferably from 50 to 100 ohm-cm.

20. A power induction device according to any one of the preceding claims, characterised in that the or each of said intermediate layers comprises polymeric material.

21. A power induction device according to any one of the preceding claims, characterised in that the or each semiconducting layer is formed of polymeric material with highly electrically conductive particles, e.g. carbon black or metallic particles, embedded therein.

22. A power induction device according to claim 20 or 21, characterised in that the said polymeric material comprises low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), cross-linked materials, for example cross-linked polyethylene (XLPE), or rubber insulation such as ethylene propylene rubber (EPR) or silicone rubber.

23. A power induction device according to any one of the preceding claims, characterised in that it is designed for high voltage, suitably in excess of 10 kV, in particular in xcess of 36 kV, and preferably more than 72.5 kV up to

very high transmission voltages, such as 400 kV to 800 kV or high r.

24. A power induction device according to any one of the preceding claims, characterised in that it is designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA and up to 1000 MVA.

25. A method of joining together in a power induction device a first cable (2) having inner first conducting means (3) and surrounding outer first electrical insulation (4), the first conducting means comprising first conductor means (22) and first cooling means (21) for cooling the first conductor means to improve the electrical conductivity of the first conductor means (22), and the first electrical insulation (4) comprising a first inner layer of semiconducting material electrically connected to the first conductor means, a first outer layer of semiconducting material connected to a controlled electric potential, e.g. earth potential, along its length, and a first intermediate layer of solid electrically insulating material between said semiconducting first inner and outer layers, and a second cable (5) having inner second conducting means (6) and surrounding outer second electrical insulation (7), the method comprising removing the electrical insulation from an end portion of each cable (2, 5) to reveal the underlying conducting means (3, 6), joining together the said end portions of the first and second conducting means (3, 6) so that the conducting means are joined together end to end at a joint (8), and surrounding the joint and said end portions of the inner first and second conducting means (3, 6) with polymeric electrically insulating means (9).

26. A method according to claim 25, characterised in that said polymeric electrically insulating means (9) is applied as a prefabricated sleeve surrounding the joint and said end portions of the first and second conducting means.

27. A method according to claim 25, characterised in that said polymeric electrically insulating means (9) is extruded around the joint and said end portions of the first and second conducting means.

28. A method according to claim 25, characterised in that said polymeric electrically insulating means (9) is applied as a polymeric tape around the joint and said end portions of the first and second conducting means.

29. A method according to claim 28, characterised in that the polymeric tape is cross-linked.

30. A method according to claim 28, characterised in that the polymeric tape contains a cross-linking agent which is cross-linked by the application of heat and pressure after the tape has been wrapped around the joint and said end portions of the first and second conducting means.

31. A method according to any one of claims 25 to 30, characterised in that said polymeric insulating means (9) has an inner layer of semiconducting material.

32. A method according to any one of claims 25 to 31, characterised in that said polymeric insulating means (9) has an outer layer of semiconducting material.

33. A method according to any one of claims 25 to 32, characterised in that said first conductor means comprises superconducting means.

34. A method according to any one of claims 25 to 33, characterised in that said second conducting means comprises second conductor means comprising superconducting means and second cooling means for cooling the second conductor means to superconducting temperatures.

35. A method according to claim 34 when dependent on claim 33, characterised in that each cooling means comprises

an inner tube through which, in use cryogenic cooling fluid is passed, in that each superconducting means comprises elongate superconducting material helically wound around its associated inner tube, and in that the said inner tubes are joined together end to end.

36. A method according to claim 35, characterised in that the said inner tubes are joined together end to end by welding.

37. A method according to claim 35 or 36, characterised in that said superconducting materials comprise oxide superconducting means sheathed in a metallic, e.g. silver or silver alloy, sheath and in that the metallic sheaths are joined together, e.g. by soldering.

38. A method according to any one of claims 25 to 37, characterised in that the power induction device is designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72.5 kV up to very high transmission voltages, such as 400 kV to 800 kV or higher.

39. A method according to any one of claims 25 to 38, characterised in that the power induction device is designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA and up to 1000 MVA.

FIG. 1

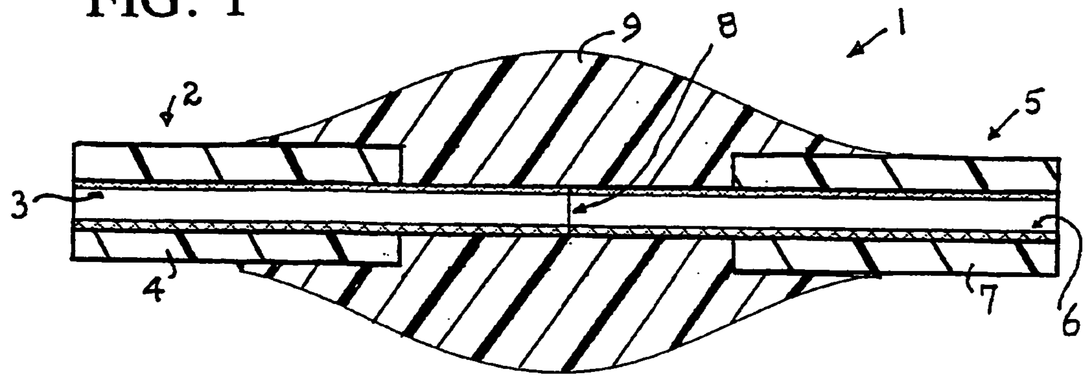


FIG. 3

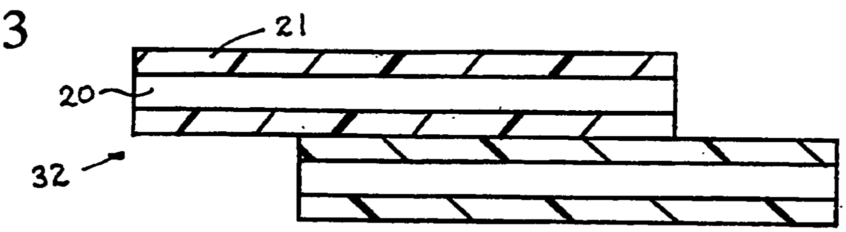
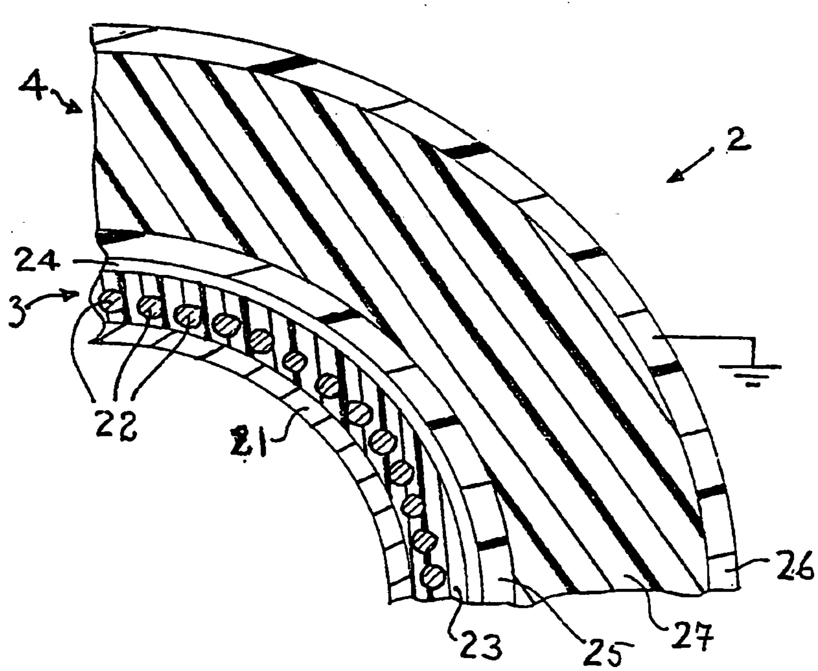


FIG. 2



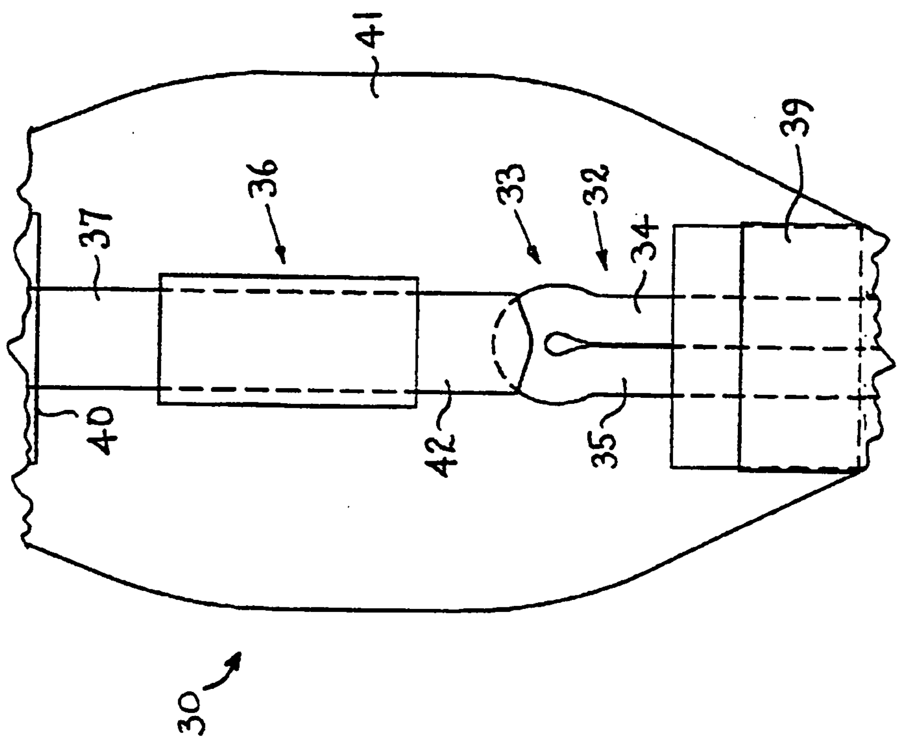


FIG. 5

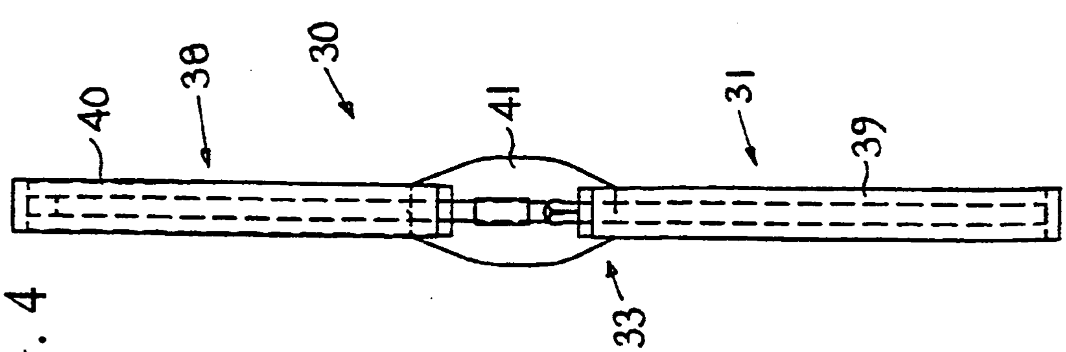


FIG. 4

INTERNATIONAL SEARCH REPORT

Inter. nal Application No
PCT/EP 98/07742

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01R4/68 H02G15/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01R H02G H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 084 307 A (SCHULTZ GORAN ET AL) 18 April 1978 cited in the application see abstract see column 2, line 61 - column 3, line 61; figures 1,2	1,7-10, 21,22
A	DE 30 08 818 A (SIEMENS AG) 10 September 1981 see page 3, line 27 - page 5, line 14; figure 1	1,5,7,8, 28,29
A	FR 2 251 938 A (PIRELLI GENERAL CABLE WORKS) 13 June 1975 see page 2, line 27 - page 3, line 8; figures 1,2	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 March 1999	11/03/1999

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	KOSAKI M ET AL: "DEVELOPMENT OF EXTRUDED POLYMER INSULATED SUPERCONDUCTING CABLE" CRYOGENICS, vol. 32, no. 10, 1 January 1992, pages 885-894, XP000319818 see page 886, left-hand column, paragraph 3 - page 887, left-hand column, paragraph 3; figures 1-3	1,12,14

1

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